Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

University of Maine.

Maine Agricultural Experiment Station

ORONO

BULLETIN No. 191. JULY, 1911

METHOD FOR DETERMINING WEIGHT OF PARTS OF EGGS.

MAINE
AGRICULTURAL EXPERIMENT STATION
ORONO, MAINE.

THE STATION COUNCIL.

PRESIDENT ROBERT J. ALEY, *President*
DIRECTOR CHARLES D. WOODS, *Secretary*
CHARLES L. JONES, Corinna,
SAMUEL W. GOULD, Skowhegan,
OSCAR R. WISH, Portland,
Committee of Board of Trustees
JOHN P. BUCKLEY, Stroudwater, *Commissioner of Agriculture*
EUGENE H. LIBBY, Auburn, *State Grange*
RINALDO L. CUMMINGS, West Paris, *State Pomological Society*
RUTILLUS ALDEN, Winthrop, *State Dairymen's Association*

AND THE HEADS AND ASSOCIATES OF STATION DEPARTMENTS.

THE STATION STAFF.

ADMINISTRATION	CHARLES D. WOODS, Sc. D.,	*Director*
	BLANCHE F. POOLER,	*Clerk and Stenographer*
	GEM M. COOMBS,	*Stenographer*
	RALPH K. JONES, B. S.,	*Librarian*
	CHARLES J. DUNN,	*Treasurer*
	GRACE M. COLBURN,	*Bookkeeper*
BIOLOGY	RAYMOND PEARL, Ph. D.,	*Biologist*
	EUGENE P. HUMBERT, Ph. D.,	*Associate*
	MAYNIE R. CURTIS, A. M.,	*Assistant*
	WALTER ANDERSON,	*Poultryman*
	LOTTIE E. McPHETERS,	*Computer*
CHEMISTRY	JAMES M. BARTLETT, M. S.,	*Chemist*
	HERMAN H. HANSON, M. S.,	*Associate*
	ALBERT G. DURGIN, M. S.,	*Assistant*
	ALFRED K. BURKE, B. S.,	*Assistant*
	HARRY C. ALEXANDER,	*Laboratory Assistant*
ENTOMOLOGY	OSKAR A. JOHANNSEN, Ph. D.,	*Entomologist*
	EDITH M. PATCH, Ph. D.,	*Associate*
	ALICE W. AVERILL,	*Laboratory Assistant*
HORTICULTURE	WALTER W. BONNS, B. S.,	*Associate Horticulturist*
PLANT PATHOLOGY	WARNER J. MORSE, M. S.,	*Pathologist*
	CHARLES E. LEWIS, Ph. D.,	*Associate*
	JOHN SUMMERS,	*Laboratory Assistant*

HIGHMOOR FARM, WELLINGTON SINCLAIR, *Superintendent*
ROYDEN L. HAMMOND, *Seed Analyst and Photographer*
ELMER R. TOBEY, B. S., *Inspector*
CHARLES S. INMAN, *Janitor*

S69
.E4

BULLETIN No. 191.

AN ACCURATE METHOD FOR DETERMINING THE WEIGHT OF THE PARTS OF THE EGGS OF BIRDS.*

BY

MAYNIE R. CURTIS.

During the past four years the biological work of the Maine Experiment Station has included a considerable amount of biometrical work on the egg of the domestic fowl. In 1910 an investigation of the size relations and proportion of the parts of successive eggs of the same individual hen was undertaken. This work when completed will include a study of all the eggs laid during the first or pullet year by a flock of over twenty Barred Plymouth Rock hens. In this work it is necessary to get accurate determinations of the weight of the albumen, yolk and shell of each egg.

In order that the data for this study might be accurate it was essential at the outstart to determine satisfactory methods, first, for preserving eggs for a few hours with practically no change in weight and, second, for accurately separating the parts of the egg. Since the results of the entire investigation cannot be published for some time, and since the methods worked out have proved useful in other investigations now in progress in this laboratory, it seems advisable to publish a discussion of them at this time.

METHOD FOR PRESERVING EGGS TO INSURE A MINIMUM LOSS IN WEIGHT.

It is often impossible to take data on eggs as soon as they are laid. In order to have comparable data it is therefore necessary to reduce as much as possible the error due to loss of weight from unequal evaporation. The amount of loss by

*Papers from the Biological Laboratory of the Maine Agricultural Experiment Station. No. 27.

evaporation depends upon several factors. The most important of these are: first, the length of time which has elapsed since the egg was laid, second, the humidity and temperature of the surrounding atmosphere and the rapidity with which the air surrounding the egg changes, third, the character of the shell, and, fourth, the amount of exposed surface, i. e., the size of the egg.

It seemed reasonable to suppose that the loss from evaporation would be reduced if the eggs were placed in small sealed jars immediately after laying. A preliminary experiment was performed to compare the loss of weight of eggs so preserved with that of eggs kept in the open air. September 9, 1910, twenty eggs were brought to the laboratory soon after they were laid. These were all Barred Plymouth Rock eggs laid between 8 and 11 o'clock on that morning. No two, of course, were from the same hen. The eggs were divided into two groups of ten each. The first group was numbered from 21 to 30 inclusive. Each of these eggs was sealed in a half pint Lightning fruit jar. Each jar contained a small amount of cotton to keep the egg from breaking when it was dropped into the jar. The ten eggs of the other group were numbered from 31 to 40 inclusive, and were placed in a wire basket on the laboratory table. The eggs were weighed* each day for four days, being removed from the jars just before and replaced directly after weighing. The weighing was begun at the same hour and proceeded in the same order (according to serial number of the eggs). At the end of the fourth day the eggs which were sealed in the jars were used in the separation experiment described later, but the eggs kept in the air were weighed also on the fifth and sixth days. Table No. I shows for each egg kept in the open air, (a) its daily weight; (b) its loss at each weighing from the first weight; (c) its loss in each 24 hours and its mean daily loss for both four and six days; (d) the mean loss for the ten eggs on each day; and (e) the mean daily loss on them for four and for six days. Table No. II gives the same data for the eggs kept in sealed jars except that it includes data for only four days.

*A chemical balance was used in all the weighing of eggs and parts of eggs. The weights were taken to hundredths of a gram.

TABLE I.

Data on the Weight of Eggs Kept in the Open Air.

Egg No.	31	32	33	34	35	36	37	38	39	40	Means.
Weight fresh	56.01	50.15	57.88	50.94	58.03	59.84	56.36	72.05	67.62	47.71	57.6590
Weight after 24 hours	55.90	50.05	57.77	50.85	57.94	59.74	56.25	71.92	67.52	47.66	57.5600
Loss in first 24 hours	0.11	0.10	0.11	0.09	0.09	0.10	0.11	0.13	0.10	0.05	0.0990
Weight after 48 hours	55.79	49.94	57.64	50.77	57.86	59.64	56.16	71.81	67.43	47.56	57.4600
Loss in 48 hours	0.22	0.21	0.24	0.17	0.17	0.20	0.20	0.24	0.19	0.15	0.1990
Loss in second 24 hours	0.11	0.11	0.13	0.08	0.08	0.10	0.09	0.11	0.09	0.10	0.1000
Weight after 72 hours	55.70	49.85	57.56	50.69	57.79	59.60	56.06	71.70	67.33	47.49	57.3770
Loss in 72 hours	0.31	0.30	0.32	0.25	0.24	0.24	0.30	0.35	0.29	0.22	0.2820
Loss in third 24 hours	0.09	0.09	0.08	0.08	0.07	0.04	0.10	0.11	0.10	0.07	0.0830
Weight after 96 hours	55.61	49.76	57.48	50.63	57.74	59.54	55.98	71.59	67.26	47.43	57.3020
Loss in 96 hours	0.40	0.39	0.40	0.31	0.29	0.30	0.38	0.46	0.36	0.28	0.3570
Loss in fourth 24 hours	0.09	0.09	0.08	0.06	0.05	0.06	0.08	0.11	0.07	0.06	0.0750
Mean daiiy loss for 4 days	0.1000	0.0975	0.1000	0.0775	0.0725	0.0750	0.0950	0.1150	0.0900	0.0700	0.0893
Weight after 120 hours	55.54	49.69	57.40	50.58	57.69	59.49	55.91	71.50	67.19	47.37	57.2360
Loss in 120 hours	0.47	0.46	0.48	0.36	0.34	0.35	0.45	0.55	0.43	0.34	0.4230
Loss in fifth 24 hours	0.07	0.07	0.08	0.05	0.05	0.05	0.07	0.09	0.07	0.06	0.0660
Weight after 144 hours	55.47	49.61	57.33	50.52	57.61	59.44	55.84	71.41	67.13	47.31	57.1670
Loss in 144 hours	0.54	0.54	0.55	0.42	0.42	0.40	0.52	0.64	0.49	0.40	0.4920
Loss in sixth 24 hours	0.07	0.08	0.07	0.06	0.08	0.05	0.07	0.09	0.06	0.06	0.0690
Mean daily loss for 6 days	0.0900	0.0900	0.0917	0.0700	0.0700	0.0667	0.0867	0.1067	0.0817	0.0667	0.0820

TABLE II.

Data on the Weight of Eggs Kept in Sealed Jars.

Egg No.	21	22	23	24	25	26	27	28	29	30	Means.
Weight fresh	66.77	*48.39	55.36	56.26	62.73	63.94	63.93	63.36	72.59	61.93	59.526
Weight after 24 hours	66.76	48.36	55.33	56.23	62.69	63.92	63.93	63.34	72.56	61.91	59.503
Loss in first 24 hours	0.01	0.03	0.03	0.03	0.01	0.02	0.00	0.02	0.03	0.02	0.023
Weight after 48 hours	66.74	48.35	55.30	56.20	62.68	63.90	63.91	63.34	72.54	61.88	59.484
Loss in 48 hours	0.03	0.04	0.06	0.06	0.05	0.01	0.02	0.02	0.05	0.05	0.042
Loss in second 24 hours	0.02	0.01	0.03	0.03	0.01	0.02	0.02	0.00	0.02	0.03	0.019
Weight after 72 hours	66.71	48.31	55.28	56.17	62.66	63.87	63.88	*53.33	72.50	61.85	59.456
Loss in 72 hours	0.06	0.08	0.08	0.09	0.07	0.07	0.05	0.03	0.09	0.08	0.070
Loss in third 24 hours	0.03	0.04	0.02	0.03	0.02	0.03	0.03	0.01	0.04	0.03	0.028
Weight after 96 hours	66.69	48.28	55.27	56.15	62.61	63.85	63.86	53.31	72.47	61.83	59.435
Loss in 96 hours	0.08	0.11	0.09	0.11	0.09	0.09	0.07	0.05	0.12	0.10	0.091
Loss in fourth 24 hours	0.02	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.021
Mean daily loss	0.0200	0.0275	0.0225	0.0275	0.0225	0.0225	0.0175	0.0125	0.0300	0.0250	0.0228

* These eggs were accidentally cracked at the time of the weighing indicated.

A comparison of these tables shows that eggs kept in the open air lose daily from 0.04 gr. to 0.13 gr. with a mean for the first four days of 0.0893, while eggs kept in sealed jars lose daily from 0.00 to 0.04 gr. with a mean for the first four days of 0.0228. That is, keeping the eggs sealed in jars reduces the evaporation to one-fourth that which occurs in the open air.

In this laboratory egg data are usually taken within 24 and always within 48 hours after the egg is laid. The error due to evaporation which is likely to influence our results is, therefore, the loss within the first 48 hours. In this time the eggs kept in the open air lost from 0.15 gr. to 0.24 gr. with a mean of 0.199, while those kept in jars lost from 0.02 gr. to 0.06 gr. with a man of 0.042. By keeping the eggs in jars the error due to this cause was reduced to nearly one-fifth that for eggs kept in the open air. The error 0.042 is too small to influence any conclusions likely to be drawn from the data. The method of preserving the egg in sealed jars is, then, sufficiently accurate for the present work.

Tables I and II show further that there are individual differences in the amount of weight lost by eggs kept under identical conditions. For eggs kept in the open air the minimum mean daily loss for the first four days was 0.07 (egg no. 40) and the maximum was 0.115 (egg no. 38). On the sixth day these two eggs still represent the extremes* with mean daily losses of 0.0667 and 0.1067 respectively. For the eggs kept in sealed jars the minimum mean loss per day for four days was 0.0125 (egg no. 28) and the maximum was 0.03 (egg no. 29).

These individual differences are no doubt due largely to variation in the character of the shell in the eggs of different individual birds. The fact that—especially in the eggs exposed to the open air—the loss of weight in heavy eggs is greater than that in light eggs indicates that the amount of exposed surface and consequently the size of the egg is another factor. The relation between size of eggs and loss of weight is shown graphically in Fig. 73.

*Egg no. 36 also has a mean daily loss of weight of 0.0667 for six days.

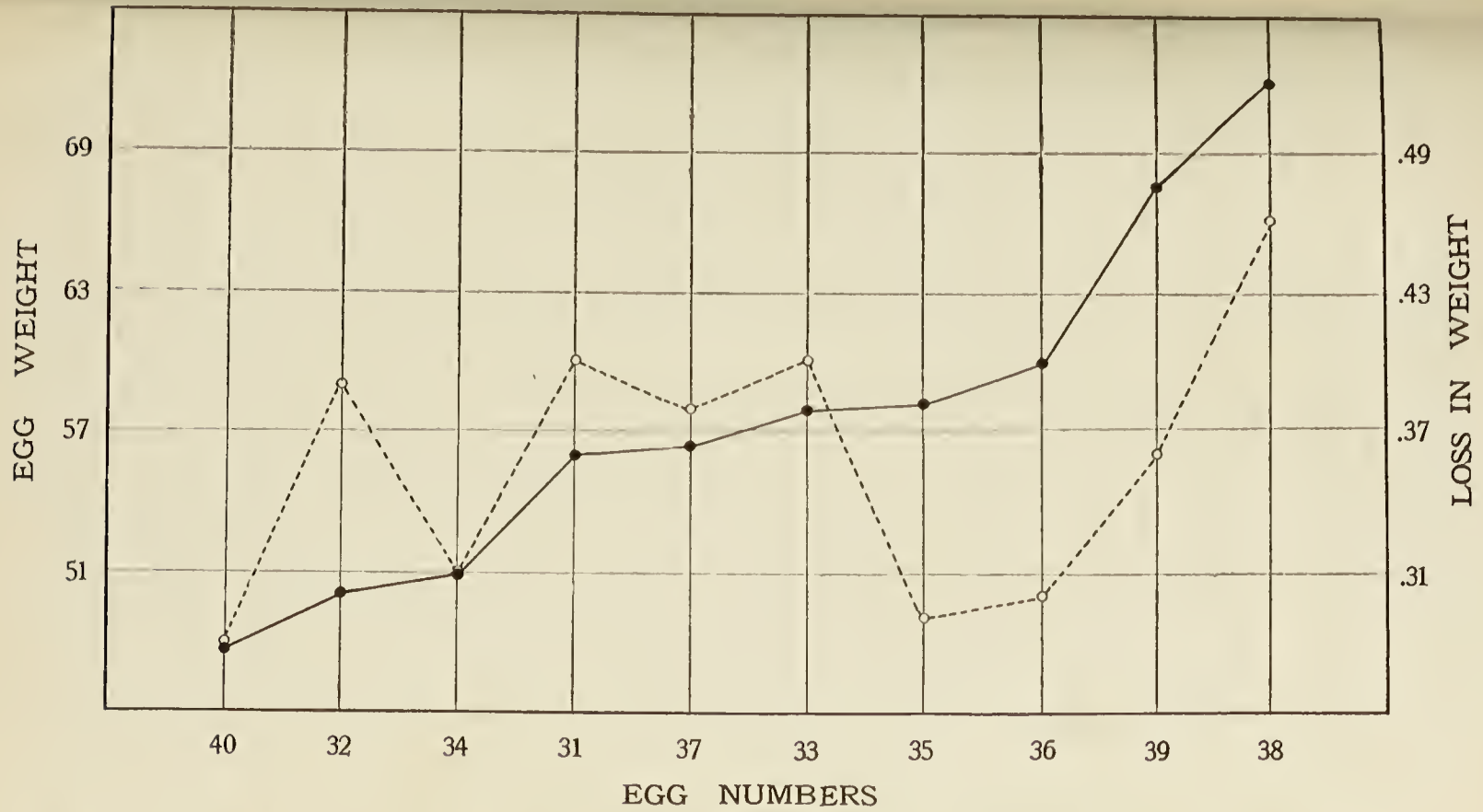

Fig. 73. Showing the relation between size of egg and its loss of weight by evaporation in open air. Explanation in text.

This diagram shows the weight of the egg and its loss of weight in four days (96 hrs.) for the set of eggs kept in the open air. The continuous line represents the weights of the eggs plotted in the order of their magnitude. The broken line represents the loss in weight in 96 hours of the same eggs. The general trend of the lines indicates that there is some positive correlation between the weight of the egg and its loss in weight by evaporation. The amount of data is too small to admit of measuring this correlation satisfactorily but the fact of its existence appears to be clear. The exceptions are such as would be expected on the assumption that the character of the shell is also an important factor.

That the comparative loss on different days must be to some extent influenced by atmospheric conditions seems reasonable, but no experiment has been performed to measure this influence. The eggs kept in sealed jars show a small variation in the daily means which cannot be analyzed by any data in hand. The mean daily loss in weight in the case of the eggs kept in the open air varies from 0.1 gr. on the second day to 0.066 gr. on the fifth day. The means for the first and second day (0.099 gr. on first and 0.1 gr. on the second) are much higher than those for the fifth and sixth (0.066 gr. and 0.069 gr. respectively) while the means for the third and fourth are intermediate (0.083 and 0.075) respectively. That is, there is a decrease in the absolute loss in weight after the second day. This is also shown by comparison of the individual means on the fourth and sixth days. In the case of every one of the ten eggs the mean daily loss is less when calculated on six days loss than when calculated on four days loss. The mean daily loss for all the ten eggs is 0.0893 when calculated on four days loss and 0.0820 when calculated on six days loss. This result might reasonably be expected since the more concentrated the albumen becomes the less rapidly would it evaporate.

Methods of Separating Eggs.

Before a study of the proportion of parts of eggs can be made it is necessary to determine an accurate method for separating these parts. In the boiled egg it is comparatively easy to separate them accurately. This method of separation was employed in some extensive but as yet unpublished work done in this laboratory. In this work the eggs were weighed fresh and dropped into boiling water; allowed to boil twenty minutes and cooled, usually, in the open air and weighed again before the parts were separated. These eggs showed a loss of from 1 gr. to 1.5 gr. in weight due to boiling and cooling. An egg that is still hot weighs more than before it is boiled but loses weight rapidly in cooling. An experiment was undertaken to test different methods of cooling the eggs.

Fourteen* eggs (nos. 6 and 8-20) were weighed and then boiled twenty minutes. Five (nos. 16-20) of these were cooled in the open air; five (nos. 11 to 15) in sealed half pint Lightning fruit jars and four (nos. 6 and 8-10) under water. Table III shows the loss of weight** of each of these eggs.

Table III.

Showing the Comparative Loss in Weight Due to Different Methods of Cooling Boiled Eggs.

Method of cooling.	Egg no.	Loss in boiling and cooling.	Method of cooling.	Egg no.	Loss in boiling and cooling.	Method of cooling.	Egg no.	Loss in boiling and cooling.
In water.	6	.91	In air.	11	1.51	In sealed jars.	16	1.76
In water.	8	1.25	In air.	12	1.75	In sealed jars.	17	1.79
In water.	9	1.08	In air.	13	1.60	In sealed jars.	18	1.68
In water.	10	1.33	In air.	14	1.54	In sealed jars.	19	1.27
			In air.	15	1.49	In sealed jars.	20	1.58
Mean loss.....		1.1425	Mean loss....		1.578	Mean loss.....		1.616

This table shows that the eggs cooled in the open air lost from 1.49 to 1.75 gr. with a mean of 1.578. Those cooled in sealed jars lost from 1.27 gr. to 1.79 gr. with a mean of 1.616.

*The experiment started with fifteen eggs but egg no. 7 was cracked when the eggs were put into the boiling water.

**Complete data for these eggs are given in table IV.

and those cooled under water lost from 0.91 gr. to 1.33 gr. with a mean of 1.1425. This experiment shows that the loss of weight in boiling and cooling is not decreased when the eggs are cooled in small closed chambers. The slight difference (0.038 gr.) in the amount of loss in the two cases is too small to be significant when such small numbers are concerned. When the eggs were cooled under water there was a decided decrease in the loss of weight. The two means are 1.578 in the case of the eggs cooled in air and 1.1425 in the case of those cooled under water. The mean loss is thus reduced by cooling in water to about three-fourths the loss when the cooling is in air. However, a loss of more than one gram in weight is too large to be overlooked in a quantitative study of the proportion of parts of eggs, and therefore any plan which involves the boiling of the eggs must be discarded in accurate work.

With a little care and practice fresh eggs can be separated accurately. This may be accomplished by a slight modification of the housewife's method. An egg should be broken near the center allowing the albumen to run into a receiving dish, holding the yolk in one half of the shell. Then turn the yolk into the other half shell and empty into the receiving dish the albumen which remained with the yolk. The chalazæ may usually be cut off by allowing each of them to slip over the shell so that they hang free with the yolk end on the broken edge of the shell. If the weight of the chalaza is insufficient, pressure may be applied at the edge of the shell or each chalaza may be clipped off with scissors. The chalazæ are allowed to fall into the receiving dish. The yolk is then poured out of the half shell on to a filter paper and rolled on the paper until the last trace of albumen is removed. It is then dropped onto the scale pan. The shell is also wiped with filter paper to remove the adhering albumen. The weight of the parts of the egg may thus be determined by weighing the egg before it is broken and then weighing the yolk and shell, which have both been dried of adhering albumen with filter paper. The weight of the albumen is then obtained by difference.

While this is obviously the most accurate method of determining the weight of the fresh albumen, it is impossible to determine the error in weighing the parts of the egg unless all the parts are weighed. The purpose of some of the preliminary

investigations was to compare the error in weighing the parts of a boiled egg with the error in weighing the parts of an egg separated fresh. The weight of the fresh albumen may be determined by using a scale pan to receive it when the egg is broken, and weighing with it the filter with which the yolk and shell are dried. This filter should either be previously balanced by another filter which is placed on the weight pan, or it may be weighed before use and its weight subtracted from the weight of the albumen and filter.

Balancing or weighing the filters was found by experience to require about one minute each. An experiment was undertaken to determine the error which would be involved in considering filters taken from the same package to be of equal weight. This experiment involves two assumptions. The first is that the weights of 50 filter papers taken in succession from one package of 100 filters is a random sample of the weights of the filter papers of the same make, number and size. The second is that the distribution of the filters (as to weight) in the package depends entirely on chance, i. e., is random. The filters used were Carl Schleicher and Schull's No. 597, diameter 150 mm. Fifty filters were weighed. The weights ranged from 1.33 to 1.83 gms. The mean weight was 1.5636. The weight of each of these fifty papers was written upon a card, and these cards were then shaken in a cylindrical box. Four wires were stretched through the box in different planes and at different levels. One hundred drawings of two cards at a time were then made, the two cards drawn being returned to the box and the box shaken between successive drawings. The difference between the weights recorded on the two cards drawn together ranged from 0.00 gr. to 0.40 gr. The mean difference was 0.1346 gr. In 88 of the 100 drawings the difference was below 0.25. In other words this indicates that if one takes a pair of filter papers at random from a package and assumes that they are the same weight he will be in error in his weights because of this assumption 0.1346 gr. on the average.

In five (26 to 30 Table IV) of the eggs separated fresh the filters used to balance the ones on which the yolk and shell were dried were taken from the pile without weighing or balancing. The error in weights is not perceptibly more in these than in the other cases where weighed or balanced filters were used.

Twenty-nine eggs were used in the experiment to compare the error in weighing in eggs separated before and after boiling. Fifteen of these eggs were separated fresh and fourteen were separated after boiling. The data collected in this experiment are shown in Tables IV and V.

TABLE IV.

Data on Eggs Separated Fresh.

Egg No.	Weight of egg.	Weight of albumen.	Per cent. albumen.	Weight yolk.	Per cent. yolk.	Weight shell, etc.	Per cent. shell, etc.	Error in weight.	Per cent. error in weight.
1.....	67.59	41.06	60.75	18.76	27.76	7.00	10.36	0.77	1.14
2.....	47.43	28.81	60.74	13.22	27.87	5.28	11.13	0.12	0.25
3.....	55.30	32.20	58.23	15.57	28.16	7.08	12.80	0.45	0.81
4.....	57.25	35.20	61.48	15.80	27.60	5.93	10.36	0.32	0.56
5.....	61.11	36.69	60.04	16.85	27.57	7.43	12.16	0.14	0.23
21*.....	66.69	41.48	62.20	17.86	26.78	7.15	10.72	0.20	0.30
22.....	48.28	26.80	55.51	16.39	33.95	4.93	10.21	0.16	0.33
23.....	55.27	32.51	58.82	16.55	29.94	6 15	11.13	0.06	0.11
24.....	56.15	33.13	59.00	16.89	30.08	6.01	10.70	0.12	0.21
25.....	62.64	38.19	60.97	17.24	27.52	6.63	10.58	0.58	0.93
26†... ...	63.85	38.38	60.11	17.72	27.75	7.59	11.89	0.16	0.25
27.....	53.86	31.10	57.74	16.51	30.65	5.99	11.12	0.26	0.48
28.....	53.31	31.73	59.52	15.97	29.96	5.34	10.02	0.27	0.51
29.....	72.47	46.01	63.49	18.21	25.13	7.79	10.75	0.46	0.63
30.....	61.83	36.14	58.45	18.72	30.28	6.90	11.16	0.07	0.11
Mean....	58.87	35.30	59.80	16.82	28.73	6.48	11.01	0.28	0.46

* The weight of eggs 21 to 30 are the weights after they had been kept in sealed jars for 96 hours. See Table II.

† In separating eggs 26 to 30 the filters used to balance those on which the yolk and shell were dried were taken from the package and were neither weighed nor balanced.

Table V gives the data for the fourteen eggs separated after boiling. It gives the weight of each egg fresh, its weight boiled, the loss of weight due to boiling and cooling, the weight of albumen, yolk, shell and membranes, the error in weights (i. e., the differences between the sum of the weights of the parts and the weight of the boiled egg), the percentage of the parts of the boiled egg, and the percentage error in weights.

TABLE V.

Data on Eggs Separated after Boiling.

Egg No.	Weight of egg fresh.	Weight of egg boiled.	Loss of weight in boiling and cooling.	Weight albumen.	Per cent. albumen.	Weight yolk.	Per cent. yolk.	Weight shell, etc.	Per cent. shell, etc.	Error in weights.	Per cent. error in weights.
6	64.99	61.08	*0.91	38.55	60.16	18.36	28.65	6.71	10.47	0.46	0.72
8	48.99	47.71	*1.25	26.47	55.45	15.36	32.17	5.62	11.77	0.29	0.61
9	59.08	58.00	*1.08	33.96	58.55	17.71	30.59	5.78	9.97	0.52	0.90
10	57.03	55.70	*1.33	31.38	56.31	17.93	32.19	5.90	10.59	0.49	0.88
11	49.61	48.10	**1.51	27.00	56.13	15.63	32.49	5.14	10.69	0.33	0.69
12	50.91	49.16	**1.75	27.05	55.02	15.91	32.12	5.75	11.70	0.42	0.85
13	49.70	48.20	**1.50	30.47	63.22	11.86	21.59	5.52	11.45	0.36	0.75
14	50.71	49.20	**1.51	27.10	55.08	16.28	33.09	5.41	11.00	0.41	0.83
15	50.75	49.26	**1.49	27.75	56.33	15.91	32.36	5.27	10.70	0.30	0.61
16	58.75	56.96	†1.76	33.39	58.59	17.51	30.78	5.87	10.30	0.19	0.33
17	59.31	57.52	†1.79	35.40	61.51	16.59	28.84	5.22	9.08	0.31	0.51
18	55.70	54.02	†1.68	30.01	55.61	17.69	32.75	6.11	11.13	0.18	0.33
19	51.01	52.47	†1.57	29.70	56.69	16.39	31.21	6.22	11.85	0.16	0.30
20	53.67	52.09	†1.58	30.31	58.25	16.17	31.04	5.38	10.33	0.20	0.38
Means	51.52	53.01	1.48	30.61	57.63	16.39	30.94	5.71	10.80	0.33	0.62

* Cooked in water. ** Cooked in oil. † Cooked in sealed jars.

A comparison of the two tables shows that in the case of eggs separated fresh the errors in weights ranged from 0.06 gr. to 0.77* gr. with a mean of 0.28, while in the case of the boiled eggs the errors in weights ranged from 0.16 gr. to 0.52 gr. with a mean of 0.33. These errors in weights were all negative. The mean error of weighing is not greater in eggs separated fresh than in those boiled before separation. It should be said, however, that in the data here presented the error of weighing does show a greater range of variation in the case of the eggs separated fresh. This is probably due entirely to chance and is of no significance. The fact that the mean error of weighing is actually less in the case of the eggs separated fresh is not significant. This is shown by the amount of variation. If a single large error like that in egg 25 had occurred instead of either of the small errors in eggs 23 or 30 the mean would have been greater than that for the boiled eggs. The errors are, however, smaller in a majority of the eggs separated.

The difference between the sum of the weights of the parts and the weight of the whole is approximately equal in eggs separated fresh and in those separated after boiling. When we consider that in the case of the eggs separated after boiling we must add to this error the also constantly negative error due to the loss in weight from boiling and cooling, it becomes apparent that the method of separating the eggs fresh involves less loss of weight. In the 14 boiled eggs used in this experiment the mean loss of weight due to boiling and cooling was 1.48 or almost five times the error in weighing.

The difference between the sum of the weights of the parts and the weight of the whole does not take into account a possible incomplete separation. That is, it is still possible that in the fresh egg a part of the albumen was weighed with the yolk and a part with the shell. If now we compare the two methods we find 59.80 as the mean percentage of albumen in the eggs separated fresh and 57.63 in the eggs separated after boiling. The mean percentage of yolk is 28.73 in the fresh eggs and 30.94 in the boiled eggs and the mean percentage of shell is

*This was the first egg separated and there was some delay due to lack of experience. A drying of the albumen may be responsible for this high loss in weight.

11.01 in the fresh egg and 10.80 in the boiled egg. That is, the percentage of albumen is higher and the percentage of yolk lower in the fresh egg than in the boiled egg. This is exactly the reverse of what would be expected if a part of the albumen had, as a matter of fact, been weighed with the fresh yolk. The percentage of shell is higher in the case of the egg separated fresh. This is what would happen if all the albumen was not removed.

There must be some explanation for this difference in the percentage of parts. An inspection of the data suggests two possibilities, each of which seems to be partly responsible for the difference in the percentage of parts in the fresh and boiled eggs which were used in this experiment. These may now be considered. (1) In spite of their large individual variability heavy eggs tend to have a higher percentage of albumen and a smaller percentage of yolk than light eggs. The group separated fresh contained a larger number of heavy eggs than the group that were boiled before separation. (2) In eggs of equal weight, those boiled before separation contained a lower percentage of albumen and a higher percentage of yolk than those separated fresh. This led to the suspicion that the loss in weight due to boiling and cooling was largely, at least, a loss to the albumen.

Figure 74 is a graphical representation of the relation between the weight of the eggs which were separated fresh and the percentages of their parts. The weights of the eggs are plotted in the order of their magnitude. They are shown by the solid black line. The line of dashes shows the percentage of albumen, the line of dots the percentage of yolk, and the dot-dash line the percentage of shell. Figure 75 shows the same thing for the eggs boiled before separation.

Both of these diagrams show considerable individual variability in the percentage of parts, but they indicate in general a positive correlation between the weight of the egg and the percentage of albumen, and an equal negative correlation between the weight of the egg and the percentage of yolk. The data here plotted showed no correlation between the weight of the egg and the percentage of shell.

The graphs also show that the group of eggs separated fresh contained several eggs heavier than the heaviest eggs in the

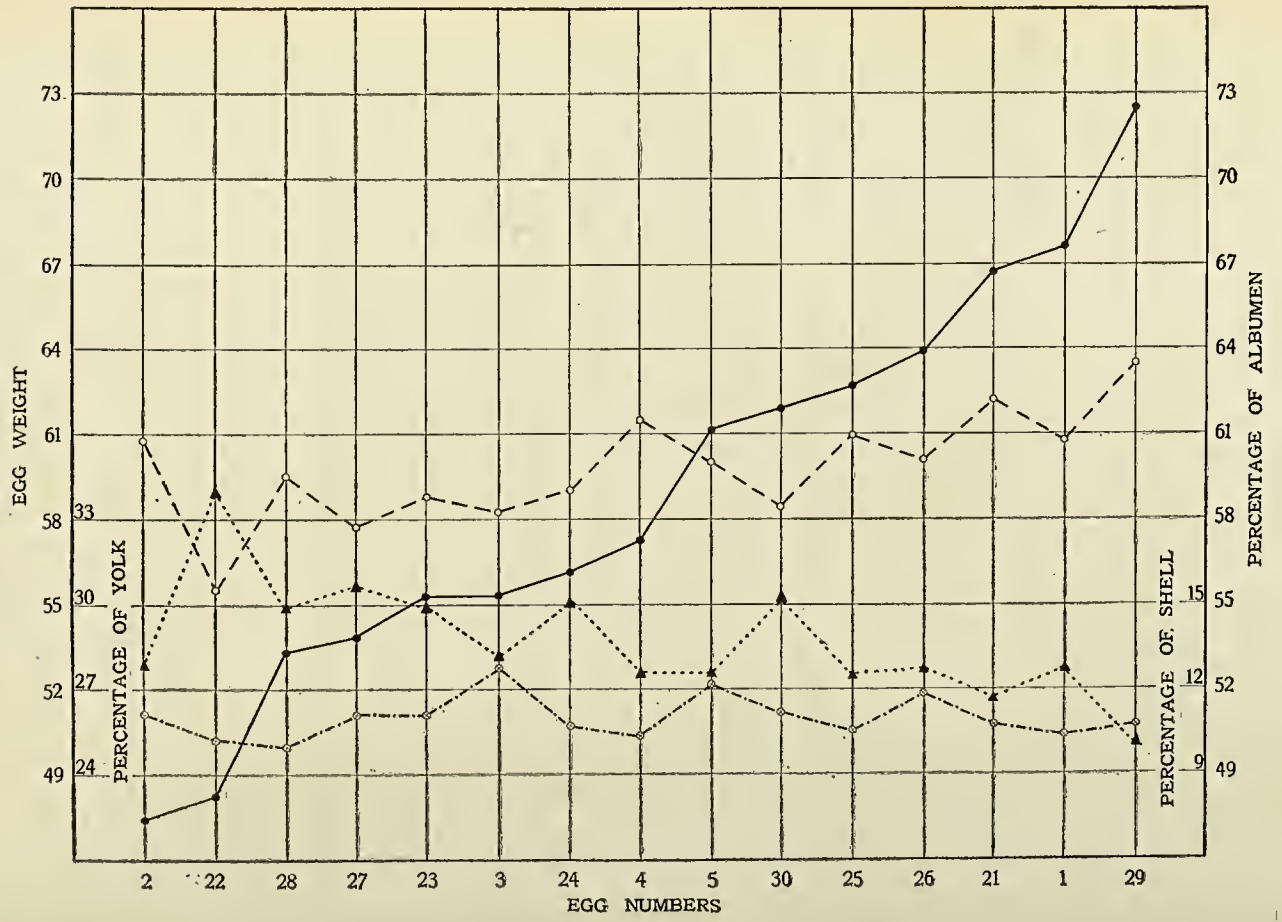

Fig. 74. Diagram showing the relation between the weight of the whole egg and its parts in eggs separated fresh. The significance of the lines is as follows: Solid, weight of egg, dash, percentage of albumen, dot, percentage of yolk, dot-dash, percentage of shell. For further explanation see text.

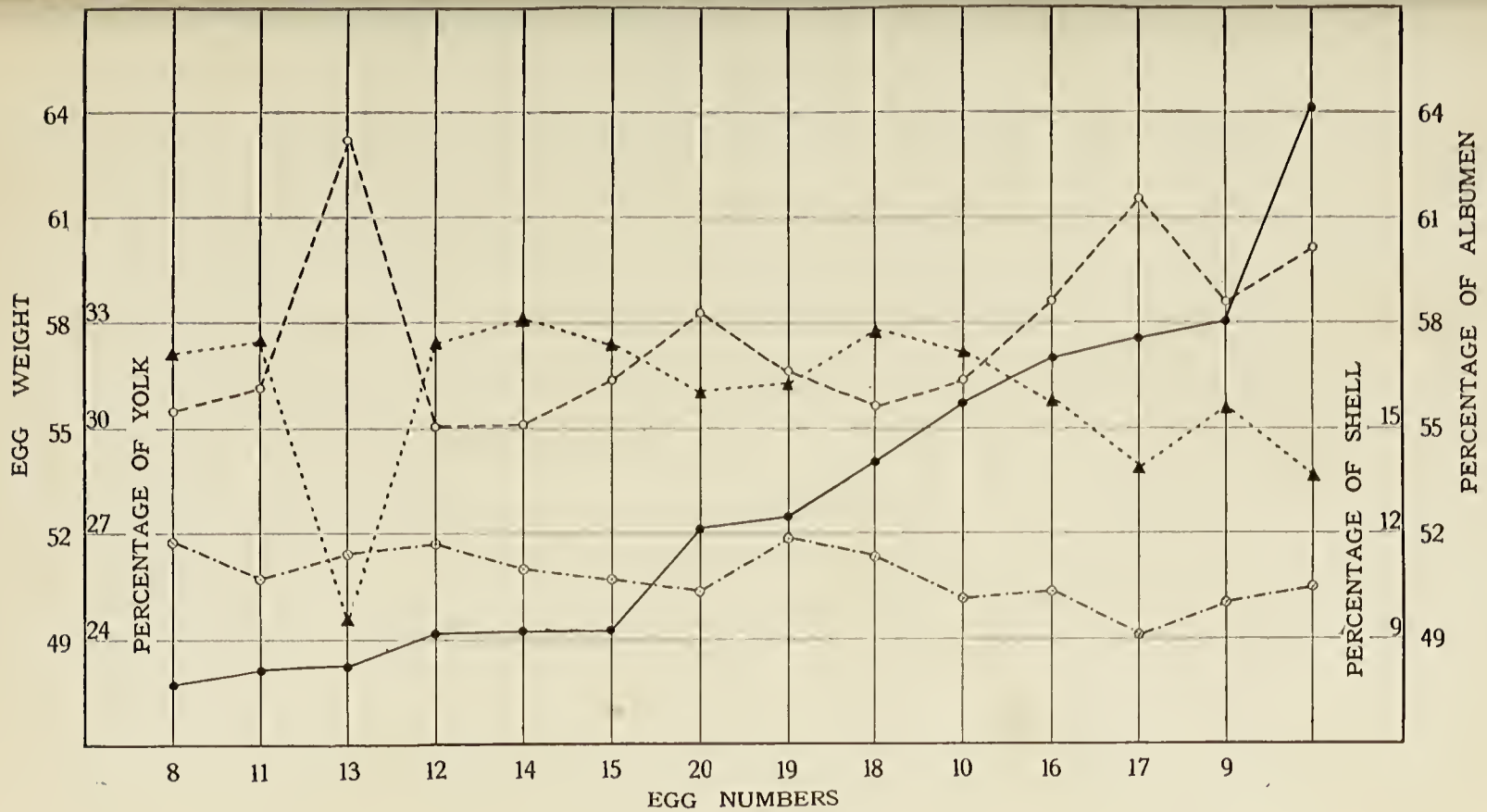

Fig. 75. Diagram showing the relation between the weight of the whole egg and its parts in eggs separated after boiling. The different lines have the same significance as in Fig. 2.

other group, while the group boiled before separation contained several more very light eggs than the group separated fresh.

A comparison of the lines showing the percentage of albumen and the percentage of yolk in the two figures shows that for a given weight of egg the percentage of albumen is higher and the percentage of yolk lower in the fresh than in the boiled egg.

If the loss of the egg in weight due to boiling and cooling is a loss in weight of albumen, the data from fresh and boiled eggs should be comparable if the eggs are of approximately equal weight and a correction factor is applied. To make this correction the loss in weight due to boiling and cooling should be added to the weight of albumen, and the percentage of parts then calculated on the basis of the fresh weight of the egg. In order to test this hypothesis seven eggs were selected from the middle of each group. These eggs in the two groups were of approximately the same weight. In the group separated fresh they varied from 53.31 gr. to 61.11 gr. with a mean of 56.04. In the other group they varied from 53.67 gr. to 59.08 gr. with a mean of 56.80. The data for these eggs is given in Tables VI and VII.

Table VI gives for the seven eggs selected from the group separated fresh the data tabled for each of the fifteen eggs in Table IV. Table VII gives the same data for the seven eggs selected from the group boiled before separation. In addition it gives the figures after correction on the assumption discussed above that the loss of weight due to boiling and cooling is a loss to the albumen. That is, the "corrected" weight of albumen given in Table VII is the weight of boiled albumen plus the total loss of weight of the eggs due to boiling and cooling. The "corrected" percentage of albumen is the percentage that this "corrected" albumen is of the weight of the fresh egg. The "corrected" percentage of yolk, of shell and membrane, and of error in weights is the percentage that each of these is of the fresh weight of the eggs.

The following relations are seen from a comparison of Tables VI and VII. The assumption made changes the mean percentage of albumen of the eggs boiled before separation from 57.93 to 59.07. The mean percentage of albumen of the eggs separated fresh is 59.26. The mean percentage of yolk of the boiled eggs is lowered from 31.06 to 30.22. The mean per-

centage of yolk in the eggs separated fresh is 29.14. The mean corrected percentage of shell of the boiled eggs is 10.20 while the uncorrected is 10.49. The percentage of shell of the fresh egg is 11.18.

TABLE VI.

Data on Selected Eggs Separated Fresh.

Egg No.	28	27	23	3	24	4	5	Means
Weight of egg	53.31	53.86	55.27	55.30	56.15	57.25	61.11	56.04
Weight of albumen	31.73	31.10	32.51	32.20	33.13	35.20	36.69	33.22
Per cent. of albumen	59.52	57.74	58.82	58.23	59.00	61.48	60.04	59.26
Weight of yolk	15.97	16.51	16.55	15.57	16.89	15.80	16.85	16.31
Per cent. of yolk	29.96	30.65	29.94	28.16	30.08	27.60	27.57	29.14
Weight of shell, etc.	5.34	5.99	6.15	7.08	6.01	5.93	7.43	6.28
Per cent. of shell, etc	10.02	11.12	11.13	12.80	10.70	10.36	12.16	11.18
Error in weights	0.27	0.26	0.06	0.45	0.12	0.32	0.14	0.23
Per cent. error in weights	0.51	0.48	0.11	0.81	0.21	0.56	0.23	0.42

TABLE VII.

Data on Selected Eggs Separated after Boiling.

Egg No.	20	19	18	10	16	17	9	Means
Weight of egg fresh	53.67	54.04	55.70	57.03	58.75	59.31	59.08	56.80
Weight of egg after boiling	52.09	52.47	54.02	55.70	56.99	57.52	58.00	55.26
Loss in boiling	1.58	1.57	1.68	1.33	1.76	1.79	1.08	1.54
Weight of albumen	30.34	29.70	30.04	31.33	33.39	35.40	33.96	32.03
Per cent. of albumen	58.25	56.60	55.61	56.34	58.59	61.54	58.55	57.93
Weight of yolk	16.17	16.39	17.69	17.93	17.54	16.59	17.74	17.15
Per cent. of yolk	31.04	31.24	32.75	32.19	30.78	28.84	30.59	31.06
Weight of shell, etc.	5.38	6.22	6.11	5.90	5.87	5.22	5.78	5.78
Per cent. of shell, etc.	10.33	11.85	11.31	10.59	10.30	9.08	9.97	10.49
Error in weights	0.20	0.16	0.18	0.49	0.19	0.31	0.52	0.29
Per cent. error in weights	0.38	0.30	0.33	0.88	0.33	0.54	0.90	0.52
Weight of albumen corrected.	31.92	31.27	31.72	32.71	35.15	37.19	35.04	33.57
Per cent. albumen corrected.	59.47	57.86	56.95	57.36	59.83	62.70	59.31	59.07
Per cent. yolk corrected	30.13	30.33	31.76	31.44	29.86	27.97	30.03	30.22
Per cent. shell, etc., corrected	10.02	11.51	10.97	10.35	9.99	8.80	9.78	10.20
Per cent. error in wts. cor'cted	0.37	0.30	0.32	0.86	0.32	0.52	0.88	0.51

It is then apparent that this correction brings the percentage of albumen and yolk of the eggs separated after boiling much nearer the percentage of the same parts in eggs separated fresh. Yet the percentage of albumen is still slightly greater and the percentage of yolk smaller in the eggs separated fresh. This is directly opposite to what one would expect if there had been an incomplete separation of the fresh egg and a part of the albumen had been weighed with the yolk. It is also

directly opposite to what would be expected from the slight difference in weight in the two groups. The mean weight of the eggs separated fresh is slightly less than the mean of the other group. It would therefore be expected that the mean percentage of albumen would be less and the percentage of yolk greater than in the other group. This difference is probably due to chance individual variations although it is possible that the yolk actually gains weight at the expense of the albumen when the egg is boiled.

The mean percentage of shell before correction, and even more after, is slightly less in the boiled than in the fresh eggs. This is what we should expect if the separation between this and the albumen were incomplete. This is, indeed, the most probable explanation of the fact. The fresh shell has a damp appearance even after it has been wiped as dry as possible with filter paper. The boiled shell looks almost dry. It is possible that the shell is somewhat dissolved in boiling and also possible that some of the difference is due to chance individual variation. All the work on the weights of the parts of eggs done at this laboratory shows that the chance individual variation in shell weight of eggs of equal weight is very large.

To summarize this portion of the work it may be said that a comparison of the method of separating the parts of eggs fresh with the method of separating them after boiling shows that the error of weighing (i. e., the difference between the sum of the weights of the parts and the weight of the whole) is not essentially different in either case. Certainly this error is not larger when the eggs are separated fresh. Further, when the eggs are separated fresh there is no appreciable loss of albumen due to drying. When eggs are separated after boiling there is *in addition* to the irreducible error in weighing an error five times as large, viz., the loss in weight due to the boiling and cooling. This error is not distributed *pro rata* between the different parts of the egg but is largely a loss to the albumen. The data here studied indicate that the yolk may even gain weight at the expense of the albumen although the range of variation and the small number of eggs considered make a positive conclusion on this point impossible.

The weight of the shell can undoubtedly be found a little more accurately in the boiled egg. Even when the shell of a

fresh egg is carefully wiped with filter paper the separation between it and the albumen is less perfect than when the albumen is coagulated. The error in shell weight in the fresh egg is, however, several times less than the error in weight of albumen in the boiled egg, the percentage of albumen being much greater in the fresh egg in spite of the small amount which is weighed with the shell.

Summary.

The purpose of this paper is to present the results of a study of methods by which an accurate determination of the weight of the several parts (albumen, yolk and shell) of the hen's egg might be made. Such methods involve (a) the prevention of loss of weight by evaporation, pending the weighing of the egg, and (b) the accurate separation of the parts of the egg for weighing. After a trial of various plans to meet these two needs the following were found to be the most accurate of any which were practicable.

1. A practical method of preserving eggs for a few hours which reduces the loss of weight by evaporation to a negligible minimum is to seal each egg as soon as possible after it is laid in a half pint Lightning fruit jar containing a cushion of absorbent cotton.

2. An accurate method of separating the parts of the egg is as follows: Break the egg near the center and allow the albumen to run into a receiving dish. Keep the yolk in one half of the shell. Then turn it into the empty half. The yolk is then dried on a filter paper. The shell is also dried on a filter. The yolk and shell are then weighed. The difference between the sum of their weights and the original weight of the unbroken egg gives the weight of albumen.